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In reply, please refer to:
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TO: Chiyome Leinaala Fukino, M.D.
Director of Health

THROUGH: Laurence Lau 2/26
Deputy Director, Environmental Health Administration

Health Resources Administration

FROM: Linda Rosen, M.D. FEB 24 2009
Chief, EMSIPSB

SUBJECT: Hospital Surveillance for Vog Effects Report

Attached for your review is the proposed report of hospital surveillance for respiratory emergencies on the Island of Hawaii during the period of increased volcanic emissions in 2008. With your approval, we would like to post this report on the Department's website. Our study found that there was a modest but statistically significant effect on emergency department visits for respiratory emergencies at Kona and Ka'u hospitals related to days of increased sulfur dioxide and particulate matter as measured by Department monitors in those areas.

The report is authored by me and Dan Galanis from EMSIPSB, but several parts of the Department collaborated in producing it. The Hazard Evaluation and Emergency Response Office, the Clean Air Branch, Air Surveillance and Analysis Section, Hawaii District Health Office and Dr. Sarah Park all made contributions and reviewed the report. In addition, the Healthcare Association of Hawaii and its' member hospitals were instrumental as they gathered and collated the surveillance information and submitted it weekly to the Department. They have also been provided the opportunity to review as was Dr. Liz Tam and consultants from the CDC.

If you have any questions, please do not hesitate to contact me.

Attachment: Vog Report

APPROVED/DISAPPROVED

Chiyome Leinaala Fukino, M.D.
Director of Health

Date: MAR 04 2009

v3011

Respiratory Emergencies presenting to Hospital Emergency Departments
And
Air Quality on the Island of Hawaii

This report will provide information gained from an analysis of respiratory emergencies presenting to hospital emergency departments and measurements of air quality since the opening of a new vent at Halema'uma'u crater on the island of Hawaii in March of 2008.

Background

Although the Kilauea volcano on the island of Hawaii has been erupting and expelling steam, gas or lava since 1983, gas and particles from the volcano increased markedly in March of 2008, worsening air quality and causing concern of possible health effects. Two vents, one at Halema'uma'u and another at Pu'u 'O'o, are primarily responsible and are shown in Figure 1. Due to the direction of the predominant trade winds, the emissions from the vents are usually blown to the southwest to the Ka'u and Kona districts, with rare days when the winds blow in the opposite direction towards Hilo. The northern areas of Kohala and the Hamakua coast have little impact.

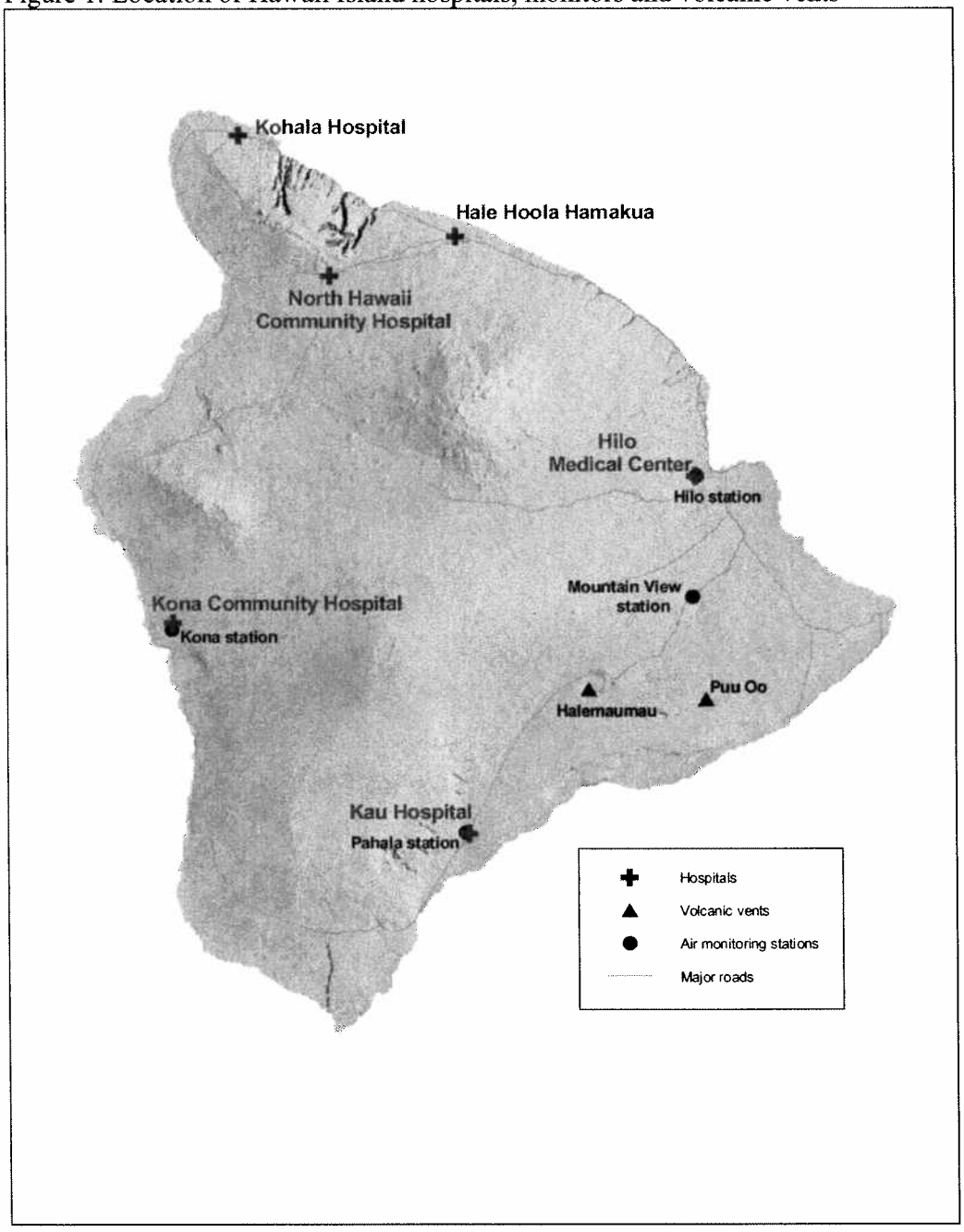
The volcanic emissions consist of a variety of gaseous and particulate substances commonly referred to as "vog". Sulfur dioxide (SO_2) and particulate matter of 2.5 microns or less ($PM_{2.5}$) are two substances found in vog that have been regulated by the U.S. Environmental Protection Agency (EPA). The detrimental health effects of SO_2 and $PM_{2.5}$ are distinct but have some overlap. The most common and concerning acute health effects described for both are difficulties in breathing. These effects are felt to occur first in individuals who already have breathing problems such as asthma or chronic obstructive lung disease, but respiratory problems may eventually affect the general population at higher levels. (1) The EPA has developed National Ambient Air Quality Standards (NAAQS) to protect public health and welfare from these harmful effects. The primary standard for SO_2 is a 24 hour average of 140 parts per billion by volume, and for $PM_{2.5}$ a 24 hour average of 35 micrograms per cubic meter of air. Both substances are measured at fixed sites by the Department of Health (DOH) at several locations on the island as shown in Figure 1. Levels recorded in previous eruptions in Hawaii rarely exceeded the NAAQS.

Methods

A method was sought to rapidly assess the health effects of vog within the community that might have implications for healthcare facilities and those responsible to warn and potentially evacuate the population. At the request of the DOH and with the assistance of the Healthcare Association of Hawaii (HAH), six hospitals on the Island of Hawaii agreed to monitor emergency department (ED) visits for respiratory emergencies that might arise from the increased volcanic emissions.

The island of Hawaii has three major hospitals Hilo Medical Center, Kona Community Hospital and North Hawaii Community Hospital (Figure 1). It also has three smaller rural hospitals at North Kohala, Hamakua and Ka'u that receive fewer patients, but represent the closest emergency care for the surrounding areas.

Figure 1. Location of Hawaii Island hospitals, monitors and volcanic vents



A case definition for an emergency condition that could be attributable to exposure to vog was developed. Because there is no characteristic presentation for an air pollutant induced emergency, general signs and symptoms of respiratory problems were chosen as the most likely emergency health effects of SO_2 or $PM_{2.5}$. A patient met the case definition of "respiratory emergency" if they had one or more of the following complaints or findings; 1) shortness of breath, difficulty breathing, 2) choking or suffocation sensation, 3) wheezing or 4) upper airway obstruction. Each hospital assigned a staff member to review the Emergency Department (ED) log book and records for patients that met the case definition. The staff received no formal training in this task. For each day, they recorded the total number of emergency department patient visits within a 24 hour period for all conditions, and the number of patients within that period who met the case definition. There were no exclusion criteria. The information was collected from the hospitals by HAH and forwarded to the DOH weekly.

Data from four DOH air quality monitors were used in these analyses: Hilo, Kona, Pahala and Mountain View. The Hilo, Kona and Pahala monitors are located one mile or closer to the hospitals at Hilo, Kona and Ka'u, respectively. The Mountain View monitor is located approximately 19 miles southwest of Hilo and 35 miles northeast of Pahala. The measurements of both SO_2 and $PM_{2.5}$ are recorded hourly, allowing both a peak hourly concentration and a mean daily concentration to be studied.

The relationship between the total number of ED visits, the number of respiratory-related ED visits and air quality was examined for SO_2 and $PM_{2.5}$ for the same day and for 24, 48 and 72 hour lag times as previous studies have shown that the detrimental effects of these exposures may be delayed. (2, 4) The association was modeled using Poisson regression with a log link function, given the non-normal distribution of daily respiratory emergency patient counts. All models controlled for the number of ED visits that were not respiratory emergencies. Air pollutant concentrations were modeled as both the hourly maximum and 24 hour mean for each day, using the lag periods described above. Pollutant levels measured at the air monitoring station nearest the hospital were used to predict respiratory patient counts for each hospital. All statistical significance testing was conducted at the 95% confidence level.

Results

Pahala had by far the highest average daily concentrations of SO_2; at least 7 times the concentrations measured at the other stations (Table 1). Pahala also had the highest peak hourly concentrations of SO_2 (not shown in Table). The highest daily averages for $PM_{2.5}$ were measured at Pahala and Kona, with the highest peak hourly measurements at Pahala. The SO_2 and $PM_{2.5}$ measurements at Hilo and Mountain View were usually low. Daily averages of SO_2 were less than 3 ppb for 90% of the days at the Hilo station, and 92% of the days at the Mountain View station. There were only 19 days (10% of the 184

day total) in which the average daily SO_2 concentration at the Hilo station met or exceeded 11 ppb, the average concentration measured at the Kona station. This level was met or exceeded at the Mountain View station on only 18 days (10% of the total). Concentrations of $PM_{2.5}$ at the Hilo station were less than 17 ug/m^3 (the average daily level measured at the Pahala station) 97% of the days at the Hilo station and 96% of the days at the Mountain View station. EPA standards for SO_2 were exceeded only at the Pahala station (26 days), which also recorded the highest number of days over the PM 2.5 standard.

Table 1. Average daily concentration of air pollutants in Hawaii County, May-October 2008

	SO_2 (ppb)		**$PM_{2.5}$ (ug/m^3)**	
	Average daily level (range)	**Number of days over standard**	**Average daily level (range)**	**Number of days over standard**
Hilo (HL11)	2 (0 - 42)	0	6 (2 – 37)	1
Kona (KN12)	11 (0 - 44)	0	22 (6 - 45)	6
Mountain View (MV17)	2 (0 - 42)	0	4 (0 – 50)	3
Pahala (PA16)	83 (1 - 311)	26	17 (4 - 78)	12

Hilo Medical Center had the greatest number of total ED visits and the lowest percent of ED visits meeting the case definition (Table 2). Ka'u Hospital had the highest percentage of ED visits for respiratory emergencies with Kona Community Hospital having the highest number of respiratory emergency visits during the study time period.

Table 2. Total and Respiratory Emergency ED Visits by Hawaii Island Hospitals, May-October, 2008

		Respiratory-Emergency ED Visits		
	Total ED Visits	**Total Visits**	**Daily Average (range)**	**Percent of Total ED visits**
Hale Ho`ola Hamakua	444	23	0.2 (0 - 2)	5%
Hilo Medical Center	16893	734	4.0 (0 - 12)	4%
Ka`u Hospital*	2017	328	1.9 (0 - 7)	16%
Kohala Hospital	615	55	0.4 (0 - 5)	9%
Kona Community Hospital	9281	1216	6.6 (1 - 15)	13%
North Hawaii Community Hosp.	5540	517	2.8 (0 - 8)	9%

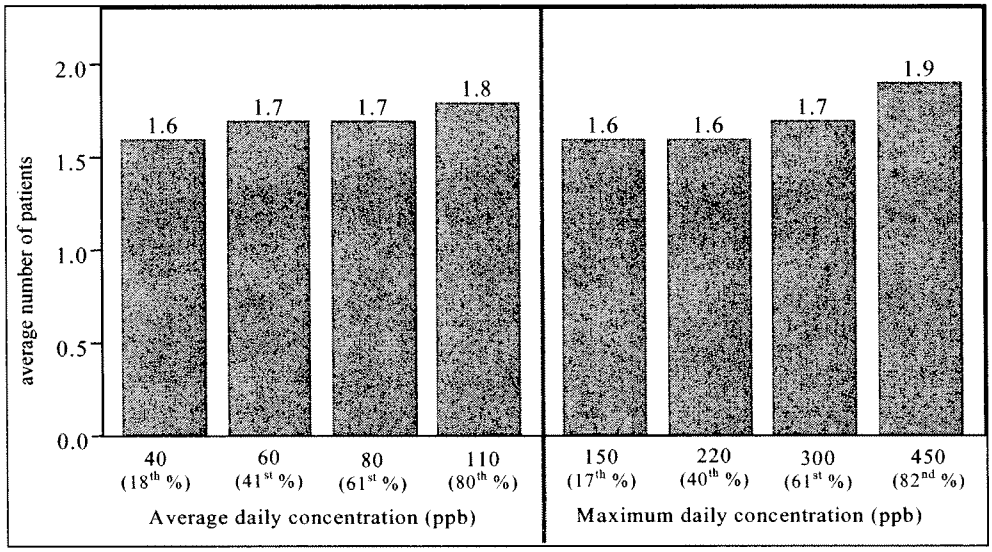
*Includes patients from both the Ka'u emergency room and clinic.

There was a significant association between the number of respiratory emergency cases at Ka'u hospital and the concentrations of SO_2 (either the daily average or

maximum level), measured at the Pahala station after 2- and 3-day lag periods. Figure 2 shows the statistical models predicted 1.6 patients 2 days after mean SO_2 levels of 40 ppb (approximately the 18th percentile of the SO_2 distribution), compared to 1.8 patients 2 days after SO_2 levels of 110 ppb (the 80th percentile). Comparing the lowest daily SO_2 level (1 ppb) to the highest level (311 ppb) resulted in 1.5 respiratory cases at Ka'u hospital compared to 2.7 cases, respectively. Similar results were found when moving across quartiles of the distribution of maximum SO_2 levels (right side of Figure 2).

Same day average levels of SO_2 measured at the Kona station were found to significantly predict the number of respiratory cases at Kona hospital. The effect size of this association was larger than that for Ka'u hospital, as the statistical model predicted 6.1 respiratory patients on a day with mean SO_2 levels of 4 ppb (approximately the 19th percentile of the SO_2 distribution at the Kona station), compared to 7.0 patients on a day with SO_2 levels of 15 ppb (the 80th percentile). There were no other significant associations between SO_2 levels after 1-, 2-, or 3-day lag periods and the number of respiratory patients at Kona hospital, however.

Figure 2. Predicted number of respiratory-related cases at Ka'u Hospital, by daily average (left side) and maximum (right side) hourly SO_2 levels (ppb), with 2-day lag.



Concentrations of PM $_{2.5}$ were generally less predictive of the number of respiratory emergency patients. The average daily levels of PM $_{2.5}$ measured at the Pahala station were found to be significantly predictive of the number of respiratory patients at Ka'u hospital, after both 2- and 3- day lag periods. The statistical models predicted 1.6 patients 2 days after mean PM $_{2.5}$ levels of 9 ug/m^3 (approximately the 20th percentile of the PM 2.5 distribution measured at Pahala), compared to 1.8 patients 2 days after PM $_{2.5}$ levels of 22 ug/m^3 (the 80th percentile). There were no significant associations with maximum levels of PM $_{2.5}$ concentration, for any lag period. There were also no associations between total ED visits and air quality at any hospital.

Discussion

Previous studies on the acute health affects of SO_2 and $PM_{2.5}$ from a volcanic source are limited. Two previous studies have looked at hospital visits, respiratory disease and air quality changes caused by the Kilauea Volcano. Manino et al published a study in 1996 on emergency department visits and hospitalizations for respiratory disease during the period 1981-1991 at Hilo Hospital and did not find strong associations between air quality and respiratory illnesses. (3) In 2004, Michaud et al published a study of ED visits at Hilo Hospital and air quality measurements from 1997-2001 that showed an association of increased asthma and COPD cases in relation to air quality with the strongest effect found for SO_2 with a 3 day lag. There were no significant associations between air quality and cardiovascular disease or other diagnoses (4) Both studies found that seasonal effects appeared to be more responsible for changes in rates of respiratory disease than air quality. However, recent output of airborne pollutants from Kilauea exceeds that which occurred during these studies.

Our study has several important limitations. First, there is no baseline data to judge whether respiratory emergencies are increasing since the increase in volcanic output. Secondly, the personnel who decided whether or not ED patients met the case definition were not trained and there may be variation between institutions and a lack of reliability in data reported. Third, the air quality measured at monitors near the hospital may not reflect the exposure of individuals who present at those hospitals for care. In addition, differences in ED utilization due to age, insurance status and other factors not controlled in this study have been described (5) and may be responsible for the differences in percentages of respiratory emergencies presenting to hospitals.

Respiratory emergencies are not the only health problem that may be caused by poor air quality. The case definition was narrowly focused on respiratory emergencies as most likely to show an increase due to sudden changes in air quality. Cardiac emergencies have also been reported to be increased in relation to poor air quality (6) and a number of other effects such as headache and dizziness are anecdotally reported. The possibility that the vog produced emergencies not included in our case definition exists. Study of other data sources such as outpatient visits and hospital admissions will be pursued to further evaluate health impacts of vog.

In conclusion, most hospitals serving the Island of Hawaii during the period from May 1, 2008 to October 31, 2008 did not have significant changes in the number of ED visits for respiratory emergencies in relation to daily measures of air quality. There were statistically significant associations at two hospitals, Kona Community Hospital and Ka'u Hospital, although the estimated impact on the number of patients was small. It is not surprising that these hospitals were affected as on most days, their surrounding area is downwind from the vents and experiences the worst air quality. Further studies are needed to look for other short term and also long term health effects that may be caused by exposure to vog.

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